Umm Al-Qura University
College of Engineering & Islamic Architecture
Mechanical Engineering Department

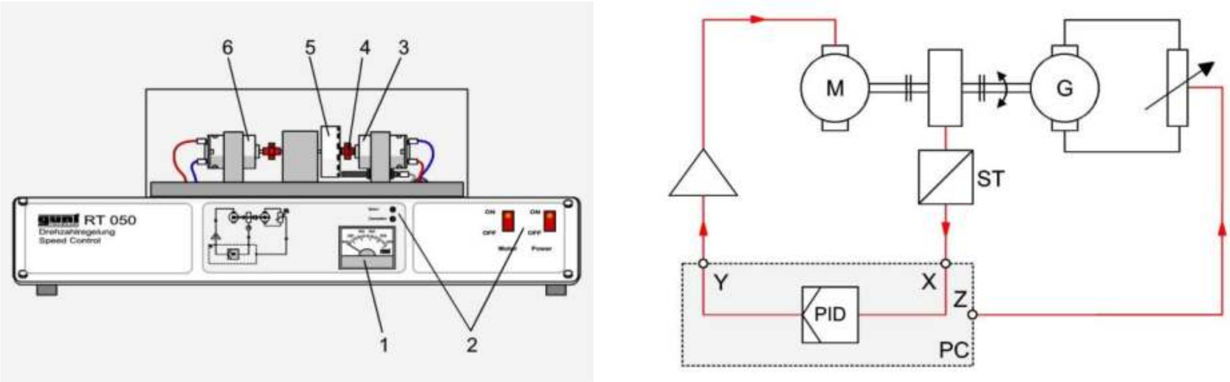
Course #: 804465 – Automatic Control Lab #8

DESIGN OF *PI* CONTROLLER FOR SPEED CONTROL APPARATUS

Objective

To design *PI* controller using Matlab SISO Design Toolbox or SIMULINK for the control of the speed of a dc motor. To perform experiments using GUNT speed control apparatus (RT 050) to study the effect of the PI controller parameters on speed of a dc motor.

Introduction



(a) (b)

Figure 1: (a) Speed control apparatus; (b) schematic diagram of the speed control apparatus. 1-tachometer, 2-displays and controls, 3-generator (G), 4-speed sensor (ST), 5-rotor-disk, 6-motor (M).

Transfer function of dc motor for ω output

$$G_m = \frac{\omega(s)}{E_i(s)} = \frac{0.0274}{0.1s + 7.6e-4}, \quad DC \quad motor$$

$$G_c = K_p + \frac{K_i}{s} = K_p\left(1 + \frac{1}{T_i s}\right) = C\left(\frac{T_i s + 1}{s}\right), \quad PI \quad controller$$

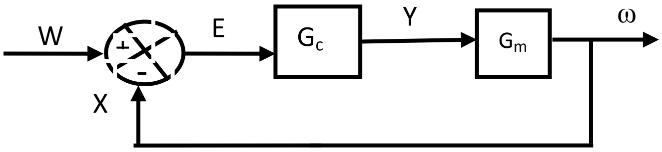


Fig. 2: Block diagram of the unit

Fig. 1 shows the speed control unit, which consists of a dc motor (M), disk or rotor and a generator (G). The transfer function G_m of the dc motor was derived during lab #4 for the angular displacement θ output as $\frac{\theta(s)}{E_i(s)} = \frac{K}{JR_a s^2 + (bR_a + KK_b)s}$. The transfer function can be modified to obtain angular speed ω by noting that ω(s) = sθ(s). Fig. 1 shows an additional rotor-disk system unlike lab # 4, during which only the shaft of the dc motor was considered. Consequently, the total mass moment of intertia *J* of the system in Fig. 1 is 0.025 kgm^{-2}. Fig. 2 shows the feedback block diagram of the speed control unit.

Implementation of PID Controller

Consider the electronic PID controller shown in Fig. 3. The values of R_1, R_2, R_3, R_4, C_1 and C_2 can be determined such that the $G_c(s) = E_o(s)/E_i(s)$, where

$$G_c(s) = 39.42\left(1 + \frac{1}{3.077s} + 0.7692s\right) = 30.3215\frac{(s+0.65)^2}{s}$$

$$G_c = K_p + \frac{K_i}{s} + K_d s = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

Lab Assignments

a. Using Matlab SISO Control Design Toolbox or SIMULINK, obtain the *PI* parameters (C and T_i and the corresponding $K_p = C*T_i$) such that the unit-step response of the system in Fig. 2 have about 15 % maximum overshoot.

Hints:

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clear all
% Initial values of Kp and Ti may be obtained by using Ziegler &
% Nichols tuning rules for PID Controller or any other method.
% The sisotool control toolbox may then be used for fine tuning
%
% PI Controller transfer function
Kp = 1;
Ti = 3;
num_gc = [Kp*Ti Kp];
den_gc = [Ti 0];
Gc = tf(num_gc,den_gc)
% DC motor transfer function for angular speed output
num = 0.0274;
den = [0.1 7.65e-4];
sys = tf(num,den)
sisotool({'rlocus','bode'}, sys, Gc)
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From the SISO Design Task, click on Analysis menu and select “Response to step command”. Right-click on the x-axis of the step response graph, select “Design Requirements” and then New. Type the given % overshoot in the appropriate box.

By changing the position of the zero of the controller (pink small circle) and the gain (pink small rectangle) on the root locus, the controller parameters and the step response can be changed and fine tuned. When the design requirements are met, click on the Design menu on the SISO Design Task, select Edit Compensator to see the final values of the parameters of the controller.

b. Experiments with the speed control unit.

Continuous control operation: Open the RT0X0 software on the PC, click on the selection button and select the speed control unit, continuous mode. Set proportional control constant $K_p = 0.02$, the integral control constant T_n (T_i) = 2, and derivative control constant $T_v = 0$, the reference W = 1000 rpm, click on charts, clear the graphs, switch on the main power switch, and then the switch for the motor and observe the resulting response for above 2 seconds. Estimate and write down the maximum overshoot from the response graph. Switch off the motor and repeat the experiment with the K_p and T_n (T_i) values obtained from matlab simulation. Observe, estimate and write down the maximum overshoot from response graph. Comment on the results.